

Three-Dimensional Structure and Evolution of the Mixed Layer in the Arabian Sea

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LONG-TERM GOALS

The long term goal of this effort is to understand better how the upper ocean responds to realistic, spatially complex wind stress patterns. Specifically, upper ocean effects related to both mid-ocean and coastal upwelling are of interest.

OBJECTIVES

The main scientific objective is to understand the physical processes that control the structure and evolution of the mixed layer in the Arabian Sea. Of particular interest are the effects of these variations and processes upon the bio-optical properties of the mixed layer and upper ocean. One of the main hypotheses of the Arabian Sea ARI is that the large scale structure of the atmospheric fields associated with the Findlater jet determines the mixed layer structure and that the variations across the northern Arabian Sea are due to the cyclonic or anticyclonic nature of the wind field on the two flanks of the jet. We are interested in observing the upper ocean structure in various regimes, including both monsoon periods as well as the near-coastal environment off Oman to observe filament structures and comparing them to those observed during the ONR Coastal Transition Zone study.

APPROACH

Our approach is to carry out upper ocean surveys in the Arabian Sea using SeaSoar, a towed undulating vehicle. The system was configured to measure temperature, pressure, conductivity, fluorescence, light transmission, dissolved oxygen, photosynthetically available radiation (PAR) and acoustic backscatter. The surveys took place during 1994 and 1995 along a repeated pattern involving mapping surveys ("radiators") on either side of the climatological Findlater jet, as well as a detailed survey in the vicinity of the moored array (Weller, Rudnick and Eriksen components). Some repeat sampling took place to investigate shorter-scale time dependence, and a filament radiator pattern was executed during the June 1995 cruise. Spatial resolution of the surveys was about 1-2 km horizontally along a cruise track, and about 25 km in the across-track direction. These data are being analyzed in cooperation with Jones (USC) to investigate how the spatial physical and biological patterns evolve and relate to wind forcing.

WORK COMPLETED

We carried out four cruises in the Arabian Sea: December 1994 (northeast monsoon), February 1995 (transitional), June 1995 (southwest monsoon), and September 1995 (transitional). We have thus

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documented the entire upper ocean seasonal evolution for a one-year period. The data from these cruises have now been completely edited, calibrated and archived. We are now carrying out the analysis phase of the project, including cooperation with scientists from other components. One manuscript is ready for submission, and others are nearing completion. Numerous presentations have been made at national or international meetings.

RESULTS

We have shown that a cool filamentary structure observed during the summer (coastal upwelling season) has many properties (latitude-scaled size, transport, and nutrient distributions) in common with features off the west coast of the US. The intense jet associated with the filament is largely in thermal wind balance. Away from the filament, during the Southwest Monsoon, lateral advection and vertical mixing often obscure the weaker effects of vertical motion driven by surface Ekman pumping. Estimates using ECMWF wind fields suggest that offshore vertical displacements are of the order of 20m over a seasonal cycle. In contrast to initial expectations of alternating upwelling and downwelling offshore of the Findlater jet, wind data indicate downward Ekman pumping throughout the year in the region of our offshore radiator, with enhanced downwelling during the Southwest Monsoon. The net result is that coastal upwelling, eddy processes and mixed layer deepening seem to play much more of a role in determining the upper ocean structure than does open-ocean upwelling.

IMPACT/IMPLICATIONS

We expect that our results will help to explain the evolution of upper ocean physical and biological patterns in the Arabian Sea. By coordination with modeling and other observational groups, we expect that results from this area will deepen our understanding of upper ocean dynamics in other regions as well. The spatial resolution of our measurements has helped to refine ideas of what is resolved with the more traditional sampling used by JGOFS chemists and biologists.

TRANSITIONS

RELATED PROJECTS

This effort is a component funded through the ONR Arabian Sea ARI. As such, we have had close cooperations with the moored array group (Weller, Rudnick and Eriksen), remote sensing personnel (Arnone, Coble, Davis), and with biological investigators (Jones, Wood, Yentsch/Phinney). Further, we have cooperated with the NRL numerical modeling team (Kindle) at sea and during the analysis stage.

REFERENCES

PUBLICATIONS (Supported by this Grant)

Brink, K.H., 1998: Hydrographic observations in the coastal ocean, *The Sea*, volume 10, (K.H. Brink and A.R. Robinson, editors), 359-366.

Brink, K.H., 1998: Time-dependent motions and the nonlinear bottom Ekman Layer, *Journal of Marine Research*, 55, 613-631.

Brink, K., R. Arnone, P. Coble, C. Flagg, B. Jones, J. Kindle, D. Phinney, M. Wood, C. Yentsch and D. Young, 1998: Monsoons Boost Biological Productivity in the Arabian Sea. *Eos*, 79, 165, 168-169.

Lee, C.M., K.H. Brink and B.H. Jones, 1998: Spatial Variations of the Upper ocean Response to Monsoonal Forcing. submitted to *Deep-Sea Research*.